THE DIET OF SPERM WHALES IN THE NORTH PACIFIC OCEAN

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Sixteen species of squid, 2 species of octopus, and 5 species of fish were found in the stomach contents of sperm whales caught in the Gulf of Alaska, Aleutian waters, and the Bering Sea. The greatest diversity of food composition was recorded in the Gulf of Alaska, especially in the eastern regions where the influence of the Alaska Current is significantly stronger. Feeding habits of male and female whales differ. The males eat eurythermic,

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cold-water, abyssal cephalopods and fish. Females feed on smaller specimens of the same cephalopods but also eat more warm-water species than do the males. The intake of cephalopod species by females is especially diverse during the summer months. The greatest diversity of food intake by males occurs in spring whereas the variety diminishes in summer.

THE DIET OF SPERM WHALES IN THE NORTH PACIFIC OCEAN

In the Gulf of Alaska, Aleutian waters, and the Bering Sea, sperm whales' food consists of 16 species of squid, 2 species of octopus, and 5 species of fish. The most diverse food composition was noted in the Gulf of Alaska, especially in the eastern parts, where the warm current exerts a strong influence. In more northerly regions the variety of sperm whales' food diminishes considerably.

Differences exist between the diets of males and females. The main diet of males consists of eurythermic and psychrophilic deepwater forms of cephalopods and fishes. Males consume the widest assortment of food in the spring. In the summer their food variety considerably diminishes.

The female diet is composed mainly of thermophilic forms although it includes the eurythermic and psychrophilic forms of the male's diet. Thermophilic forms comprise only a minor portion of the male's intake.

The adaptability of males to feed on psychrophilic forms, which is related to their ability to dive to great depths, makes possible the expansion of their habitation range into the higher latitudes. The females, limited to warmer waters by their relatively shallow diving ability, increase their food resources by adding a number of cephalopod species to their diet.

An extensive literature deals with the sperm whales' diet but little data exist on the diet of females in different regions at various seasons of the year.

Materials and Method. The data were collected during March to October 1963 and 1964 by the factory ships Dal'niy Vostok and Vladivostok. Besides the author, N. V. Doroshenko and A. A. Rovnin, two other members of the Pacific Science Research Marine Fisheries and Oceanography Institute, also participated in data collection.

Stomach contents of sperm whales are usually heavily digested and consist of squid beaks, gladii and fish bones. Whole undigested organisms are rarely encountered and then only in small quantities. During dissection of the stomachs, all well preserved organisms were extracted first and then 400-500g of squid beaks and fish bones. The basis for identification of fish were otoliths and bones. Squid were identified by beaks and by comparison with the records of earlier collections compiled by the author, with I. I. Akimushkin's help (Tarasevich, 1963), and by R. Clarke (1962). Contents of 174 stomachs

(141 males, 33 females) were examined.

Composition of sperm whales' food in different regions of the North Pacific. The food of sperm whales was examined in the Gulf of Alaska, Aleutian waters, and the Pribilof Island -- Bering Sea slope region. Hydrologic conditions of these regions differ and this fact is undoubtedly reflected in the distribution of certain cephalopod mollusk species which comprise the main diet of sperm whales.

Table 1 records the frequency of occurrence of various cephalopoda in the stomachs of sperm whales caught in the designated regions of the Pacific. Table 1 shows that sperm whale food consists of 16 species of squid*, two species of octopus, and fishes. /596

The importance of various squids as food differed from region to region. In the Gulf of Alaska, the principal species, both by quantity and frequency of occurrence, were: Galiteuthis armata, Gonatus fabricii var separata, and Chiroteuthis veranyi. Taonius pavo, Gonatus fabricii, and Gonatus magister were frequently consumed but in small quantities. Meleagroteuthis separata and Octopodateuthis longiptera also occurred. In Aleutian waters the main species were: G. fabricii var. separata, G. fabricii, T. pavo, and G. armata.

The greatest diversity of whale diet was noted in the Gulf of Alaska but the variety of food composition diminished in the Bering Sea (especially in the northeast region).

I. I. Akimushkin (1954), after studying sperm whales' food in Kurile waters, concluded that among cephalopodic mollusks some species prefer regions with warmer waters and some prefer colder waters. Table 1 also demonstrates that among cephalopoda counted as whale food, such species as Ch. veranyi, Moroteuthis robusta, O. longiptera, M. separata, No. 5 (according to Akimushkin, 1954), and Alloposus mollis, (which I. I. Akimushkin regarded as more thermophilic species) /597 prefer regions influenced by warm currents (Gulf of Alaska). Gonatus magister and No. 5b squid (according to Akimushkin, 1954) are probably relatively thermophilic.

*Unclassified squids were designated by constant numbers conditionally assigned to each of them by I. I. Akimushkin (1945). Squid No. 5 has been classified by Clarke (1962) as Cucioteuthis unquiculata for the Atlantic.

Table 1

Food of Sperm Whales in Different Regions of North Pacific in 1963-1964

Species of Squid	Frequency of Occurrence in % of total no. of spec. in stomachs			Persistence of Species*		
	Gulf of Alaska (63 samples)	Aleutian Waters (97 samples)	Pribilof Is. Bering Sea Slope (24° S.)	Gulf of Alaska	Aleutian Waters	Pribilof Is.-Bering Sea Slope
Gaiteuthis armata (Youbin)	25,2	14,7	18,3	93,6	82,7	100
Gonatopsis borealis (Sasaki)	1,5	2,29	3,3	46	55,1	45,8
Onychoteuthis banksii (Leach)	0,4	0,2	—	9,5	16	—
Gonatus fabricii (Lichtenst)	7,3	17	24	72	77	95,8
G. fabricii var. separata 5**	18,8	26,8	38,3	92	89,6	100
G. magister (Berry)	7,3	8,9	3,5	69,4	79,3	83,3
Melanoteuthis separata (Sasaki)	5,5	4,8	4,1	90,4	53,9	75
Octopoteuthis longipiera (Pfefer)	4,03	0,8	1,1	80,9	33,3	37,5
Moroteuthis robusta (Verrill)	2,3	1,4	0,7	27,7	49,4	45,8
Taonius pavo (Lesueur)	8,1	10,9	3,6	84,1	73,1	66,6
Chiroteuthis veranyi (Ferussac)	10,9	3,8	1,1	80,9	70,1	50
Architeuthis japonica (Pfefer)	0,05	0,07	0,1	11,1	41,8	25
№ 5	1,1	0,59	0,9	36,5	31	41,6
№ 5b	0,11	0,09	0,2	14,2	9,1	20,8
№ 7	0,14	0,04	0,1	4,7	8,09	12,5
№ X	0,15	0,02	0,18	1,5	4,5	25
Allopesus mollis (Verrill)	1,02	0,04	0,1	36,3	6,8	8,3
Octopus gilbertianus (Berry)	0,11	0,6	0,17	7,9	14,9	12,4
Fish	—	—	—	32,0	68,0	—

*Number of stomachs in which given species was found (in % of the total quantity of investigated stomachs).

**A form of Gonatus fabricii which differs in many details from the typical form and was separated by I. I. Akimushkin (1963).

According to Ye. I. Betesheva's and I. I. Akimushkin's data (1955), /597
G. magister comprised up to 28 percent of the cephalopods in the whale diet, while within South Kurile waters, squid No. 5 comprised 2.3 percent.

Table 2

Fishes Consumed by Sperm Whales in North Pacific

Name of Fish	Gulf of Alaska		Aleutian Waters	
	No. of Stomachs	Frequency of Occurrence, %	No. of Stomachs	Frequency of Encounter, %*
Macrouridae	3	17.6	3	8.3
Alepisaurus zeschulpus	10	58.8	11	30.5
Sebastodes alutus	6	35.2	6	16.6
Aptocyclus ventricosus	1	5.8	18	50
Lampreys	—	—	4	11.1
Total No. of Stomachs	17	—	36	—

*Number of stomachs (in percent of total quantity of investigated stomachs) in which given species of fish were encountered.

In the Pribilof Island-Bering Sea slope region, according to Table 1, G. magister comprised 3.5 percent, and squid No. 5b, 0.2 percent, of the total squid mass found in whale stomachs. Thus the importance of these squid to whale diet decreases as one moves north.

G. fabricii var. separata, G. fabricii, G. armata, T. pavo, and Octopus gilbertianus prefer colder water according to our data which corroborate I. I. Akimushkin's opinion.

G. armata and T. pavo, the most eurythermic among the species counted, are the most widely distributed (I. I. Akimushkin, 1963).

The reaction of cephalopods to differing water temperatures, salinity, and other environmental factors is probably the reason for the limited sperm whale diet in the Bering Sea where waters are colder. This may also be the reason for the more diverse diet in the Gulf of Alaska where a warm current exerts a great influence.

As previously mentioned, besides squids and octopii, sperm whales also consume fish, which were observed in 30.4 percent of the stomachs examined (53 whales). Of this number, 36 sperm whales (60%) were caught in Aleutian waters and 17 (32%) in the Gulf of Alaska.

The composition, by species of fish, found in the sperm whale diet is

presented in Table 2. Macrurids, alepisaurs, and lampreys occurred 1-3 specimens per stomach but lumpsuckers (Ed. note: family Cyclopteridae) reached 50 per stomach. Large quantities of perch bones were encountered but were not counted. Fish were found more frequently in whale diet in spring rather than in summer, i.e., of the 53 sperm whales whose stomachs contained fish, 37 (69.9 percent) were caught in March-April and 16 (30.1 percent) in July-August. These data demonstrate that sperm whales supplement their diet with fish in the spring when squids are not plentiful.

Differences between the diets of males and females. Sperm whales are characterized by a sharply pronounced sexual dimorphism. They are 1.5 times larger than females. Difference in size and other morphological features determines the difference between males and females in maximal diving ability (the males dive deeper) and their capacity to forage for food (males range further). Under certain conditions, it also determines the different composition of their food. /598

Analysis of whale food in Kurile waters (Tarasevich, 1963) showed that in this region food of males and females differed in different months.

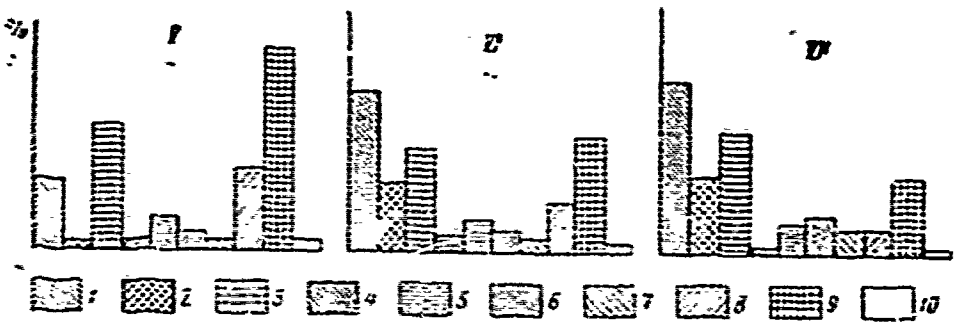

Fig. 1. Quantity (in %) of Individual Squid Species in the Stomachs of Sperm Whale Males in the Gulf of Alaska
1 - G. armata, 2 - G. fabricii, 3 - G. fabricii var. separata, 4 - O. longiptera, 5 - G. magister, 6 - M. separata, 7 - M. robusta, 8 - T. pavo, 9 - Ch. veranyi; V - VII - months.

Observations in the Gulf of Alaska confirmed results obtained in Kurile waters: the food of males consisted mainly of psychrophilic, eurythermic, and more deepwater species. Thermophilic species comprised a large part of the female diet. For example, the psychrophilic squid species, G. armata, G. fabricii var. separata,

G. fabricii and T. pavo comprised 76.3 percent of males' food but only 45.3 percent of females' food. Among psychrophilic forms found in food of females, it should be noted that the largest quantity (18.4 percent) consisted of the eurythermic G. armata. This squid also comprises 30.5 percent of the male diet.

Among thermophilic squids, Ch. veranyi, M. separata, O. longiptera, and G. magister comprised 23 percent of G. fabricii, and O. gilbertianus composed 15.3 percent of males' food but only 5.58 percent of females' diet. Fish were encountered more often in the stomachs of males than in female stomachs. In the Gulf of Alaska, for example, fish were found in 13 of 34 (38.2 percent) male stomachs and 4 of 29 (13.7 percent) of females.

To illustrate how the food composition of males and females varied in time, Figures 1, 2, and 3 show the quantity (in percentage) of different species of squid found in the stomachs of males during various months in the North Pacific. In the Gulf of Alaska during May (Fig. 1), the males consumed various species of squid, among which Ch. veranyi predominated. In June and especially in July, the quantity of this species in male food decreased and their diet consisted mainly of G. armata, G. fabricii var. separata, and G. fabricii with smaller quantities of other squid. The tendency of males to switch in summer to a diet composed mainly of these three squid was also observed in Aleutian waters (Fig. 2). The same three /599
species of squid were the main diet of whales during July and August near the Pribilof Island and along the Bering Sea slope (Fig. 3). However, in August sperm whale diet was somewhat more diverse on the Bering Sea shelf than it was around the Pribilof Islands.

The great diversity of diet during autumn months probably indicates that such male diet items as G. fabricii var. separata, G. fabricii, and G. armata do not multiply sufficiently during this period so that whales are forced to feed on other squid and fish. As summer approaches, cephalopods (the preferred food) accumulate, males begin to feed on them and so their diet becomes more monotonous.

The seasonally monotonous male diet is corroborated by the fact that in Aleutian waters, whale groupings are considerably longer in summer than spring (Tarasevich, 1967). Large groupings can exist only if there are large accumulations of squid. On the Bering Sea slope a certain deviation from this pattern was observed: the male diet in August, as has been mentioned, was more diverse than that near the Pribilof Islands. It is possible that this phenomena is related to an insufficient summer accumulation of squid in northern regions where the influence of a warm current is weaker.

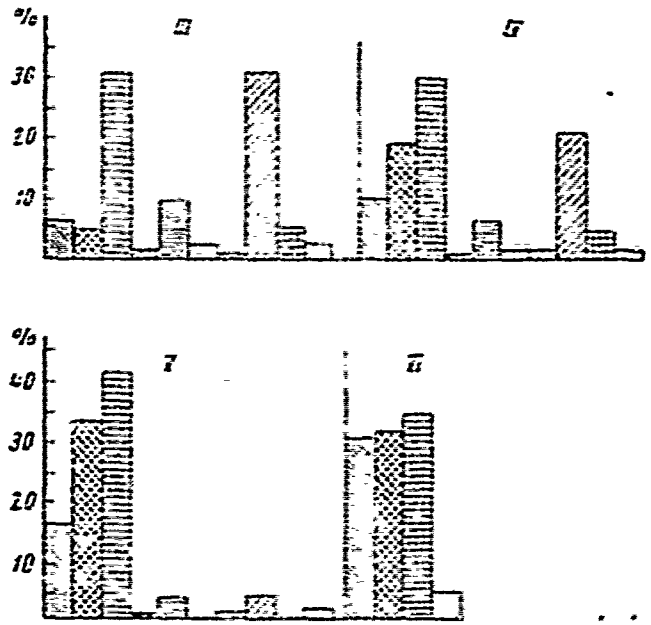

Fig. 2. Quantity (in %) of Individual Species of Squids in the Stomachs of Male Sperm Whales in the Aleutian Waters
III - VI - Months; remaining markings are the same as in Fig. 1.

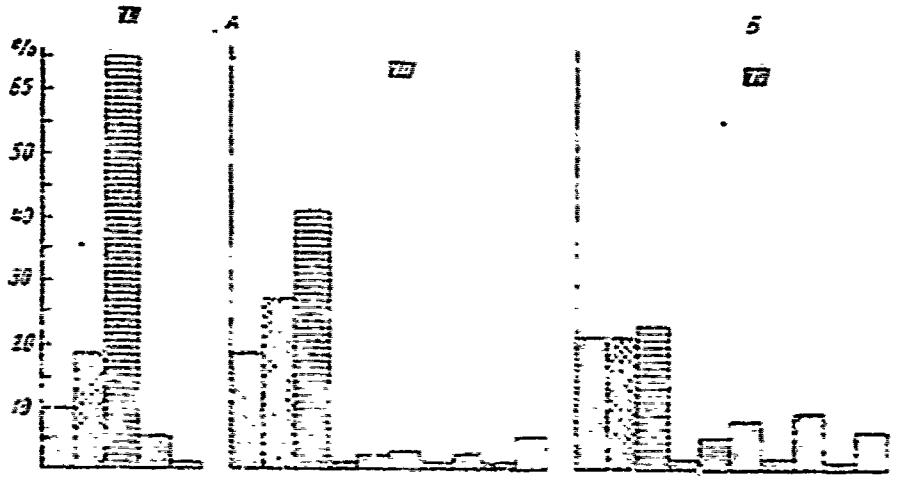

Fig. 3. Quantity (in %) of Individual Species of Squids in the Stomachs of Male Sperm Whales
A - Pribilof Is.; B - Bering Sea slope; VII - VIII - Months; remaining markings are the same as in Fig. 1.

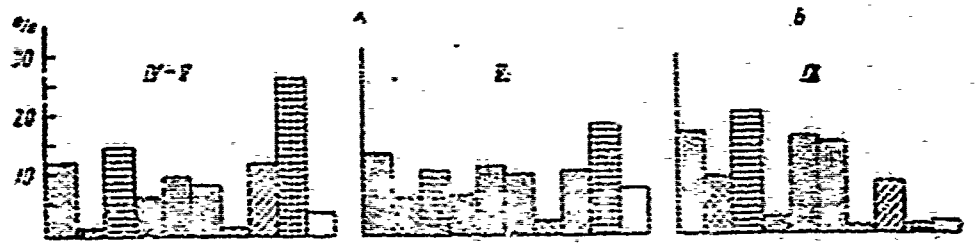

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Fig. 4. Quantity (in %) of Individual Species of Squid in Stomachs of the Females

A - Gulf of Alaska, B - Aleutian Waters, IV - V, VI, IX - Months; remaining markings are the same as in Fig. 1.

Completely different patterns are observed in the female diet (Fig. 4). During April and May, the main female food was Ch. veranyi along with many different cephalopods. In June, the composition ratio between individual species changed somewhat but the diet remained diverse. The same pattern was observed for females in Aleutian waters in September, although certain thermophilic squids were consumed there in lesser quantities.

Our data substantiate the diversity of food composition of female sperm whales. Change in their diet is only in quantitative ratios of different squid species which vary with season and location.

The foraging range of females is limited by two factors: (1) shallow diving capacity (determined by their smaller size) and (2) warmer waters (determined by temperature requirements of offspring), (Zenkovich, 1952). Food resources are expanded by increasing the species of cephalopods in their diet.

Sperm whale diet can vary during individual years depending on hydrological factors. Generally, the variety of whale diet varies with sex, location of feeding grounds, and season of year.

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